US009183678B2

(12) **United States Patent**
Suto et al.

(10) **Patent No.: US 9,183,678 B2**
(45) **Date of Patent: *Nov. 10, 2015**

(54) **IMAGE PROCESSING DEVICE, IMAGE PROCESSING METHOD, AND PROGRAM**

(71) Applicant: **SONY CORPORATION**, Tokyo (JP)

(72) Inventors: **Yasuhiro Suto**, Tokyo (JP); **Masaki Fukuchi**, Tokyo (JP); **Kenichirou Ooi**, Kanagawa (JP); **Jingjing Guo**, Tokyo (JP); **Kouichi Matsuda**, Tokyo (JP)

(73) Assignee: **Sony Corporation**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **14/527,148**

(22) Filed: **Oct. 29, 2014**

(65) **Prior Publication Data**

US 2015/0049116 A1 Feb. 19, 2015

Related U.S. Application Data

(63) Continuation of application No. 12/984,847, filed on Jan. 5, 2011, now Pat. No. 8,896,628.

(30) **Foreign Application Priority Data**

Feb. 2, 2010 (JP) 2010-021368

(51) **Int. Cl.**
G09G 5/00 (2006.01)
G06T 19/00 (2011.01)

(52) **U.S. Cl.**
CPC ***G06T 19/006*** (2013.01); ***G09G 5/00*** (2013.01)

(58) **Field of Classification Search**
USPC 382/103; 345/8
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2004/0080467 A1* 4/2004 Chinthammit et al. 345/7
2005/0093889 A1* 5/2005 Sauer et al. 345/633

(Continued)

FOREIGN PATENT DOCUMENTS

JP 2003-281297 10/2003
JP 2008-304268 12/2008
JP 2009-037392 2/2009

OTHER PUBLICATIONS

Dec. 2, 2014, JP communication issued for related JP application No. 2010-021368.

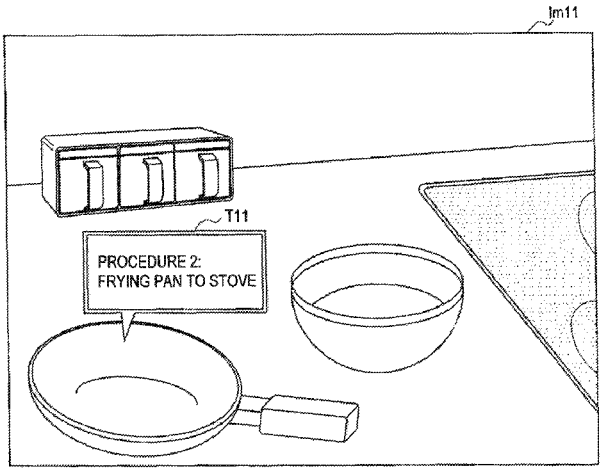
(Continued)

Primary Examiner — Phi Hoang
(74) *Attorney, Agent, or Firm* — Paratus Law Group, PLLC

(57) **ABSTRACT**

There is provided an image processing device including: a data storage unit storing feature data indicating a feature of appearance of one or more physical objects; an environment map building unit for building an environment map based on an input image obtained by imaging a real space and the feature data, the environment map representing a position of a physical object present in the real space; a control unit for acquiring procedure data for a set of procedures of operation to be performed in the real space, the procedure data defining a correspondence between a direction for each procedure and position information designating a position at which the direction is to be displayed; and a superimposing unit for generating an output image by superimposing the direction for each procedure at a position in the input image determined based on the environment map and the position information, using the procedure data.

9 Claims, 18 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2007/0273610	A1*	11/2007	Baillot	345/8
2008/0304707	A1*	12/2008	Oi et al.	382/103
2009/0189974	A1	7/2009	Deering	
2009/0245681	A1	10/2009	Kobayashi	
2010/0033404	A1	2/2010	Hamadou et al.	

OTHER PUBLICATIONS

A.J. Davison, "Real-Time Simultaneous Localisation and Mapping with a Single Camera", Proceedings of the 9th IEEE International Conference on Computer Vision, vol. 2, pp. 1403-1410 (reprint shows pp. 1-8) (2003).

* cited by examiner

FIG.1A

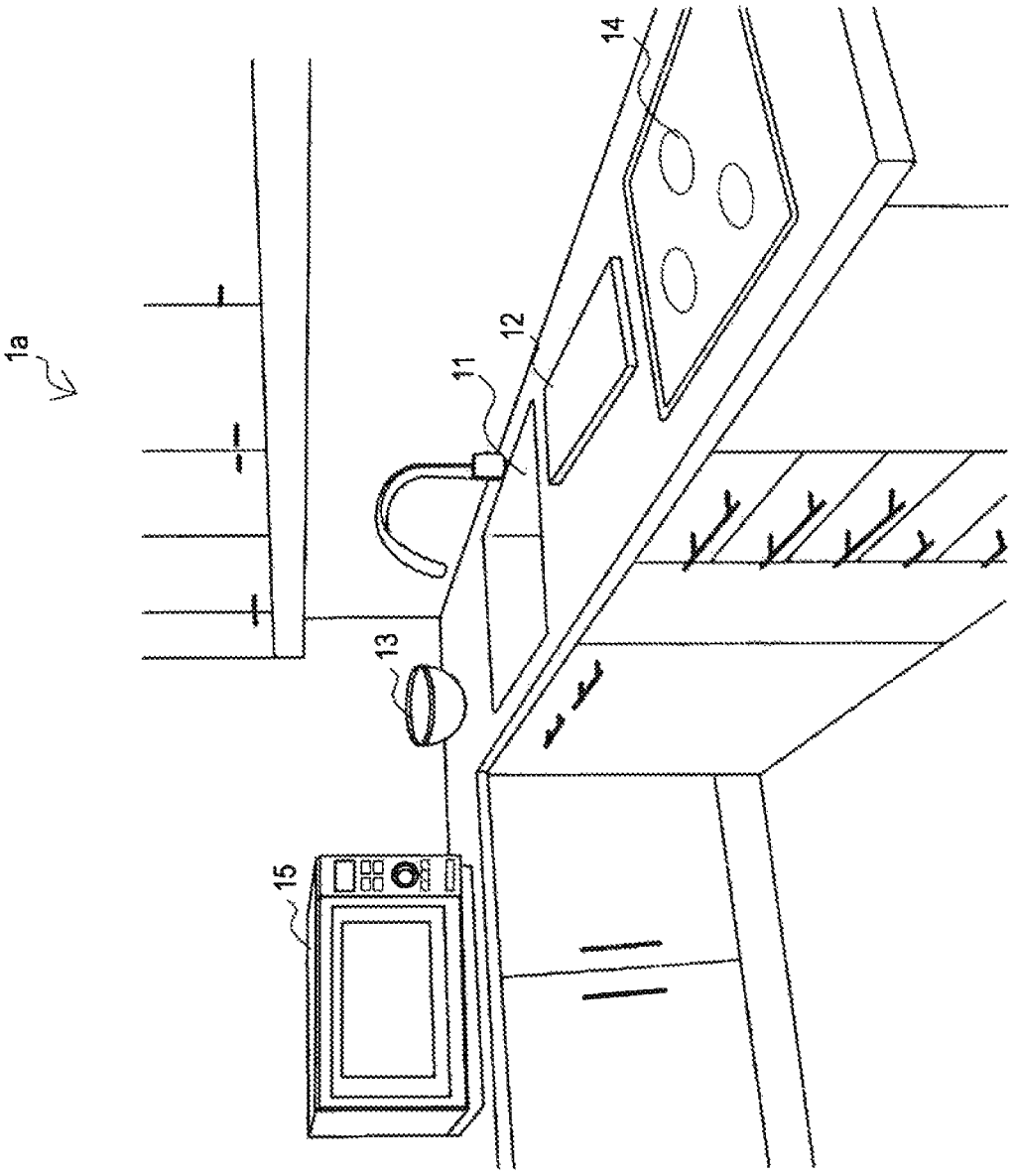


FIG.1B

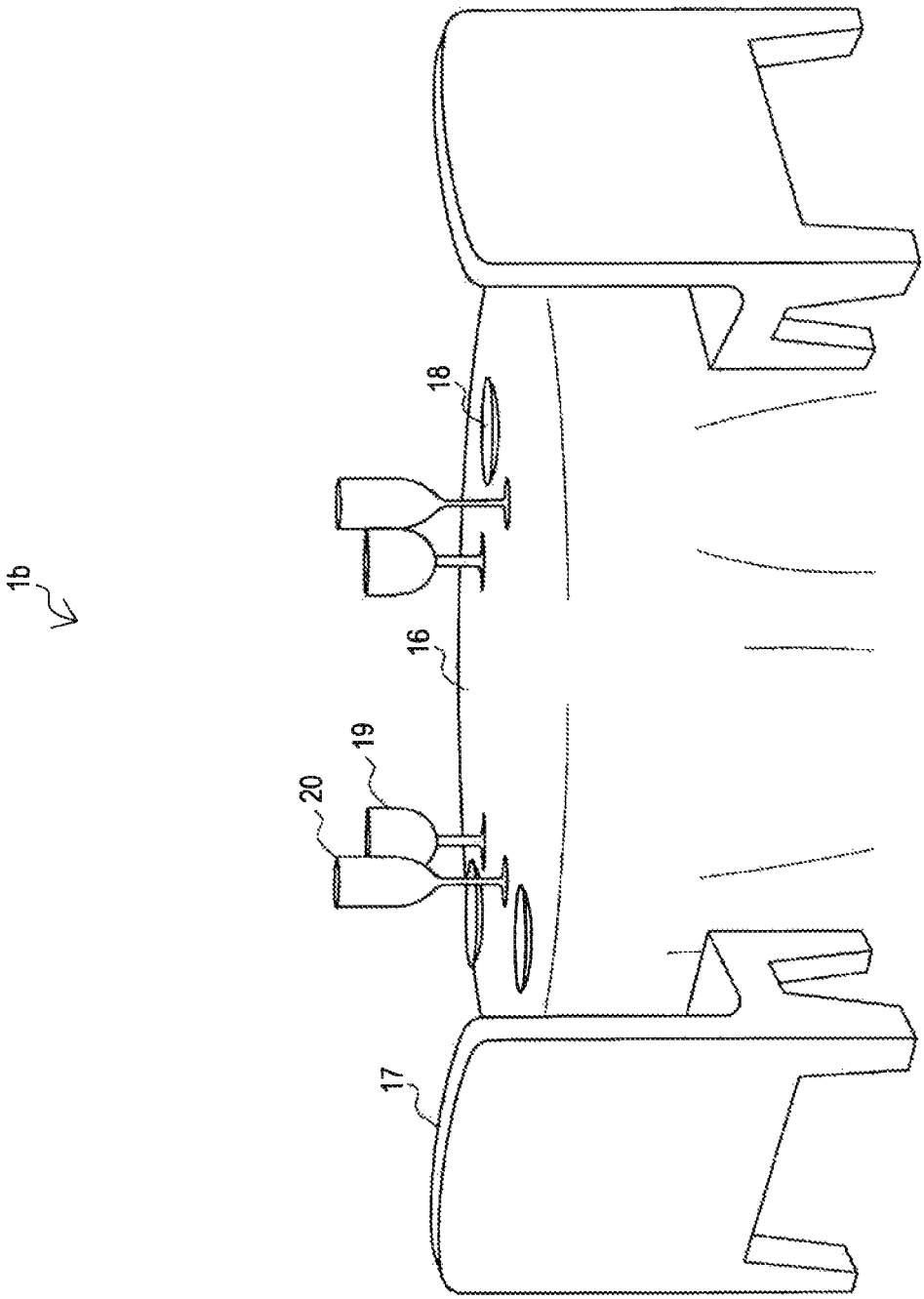


FIG.2B

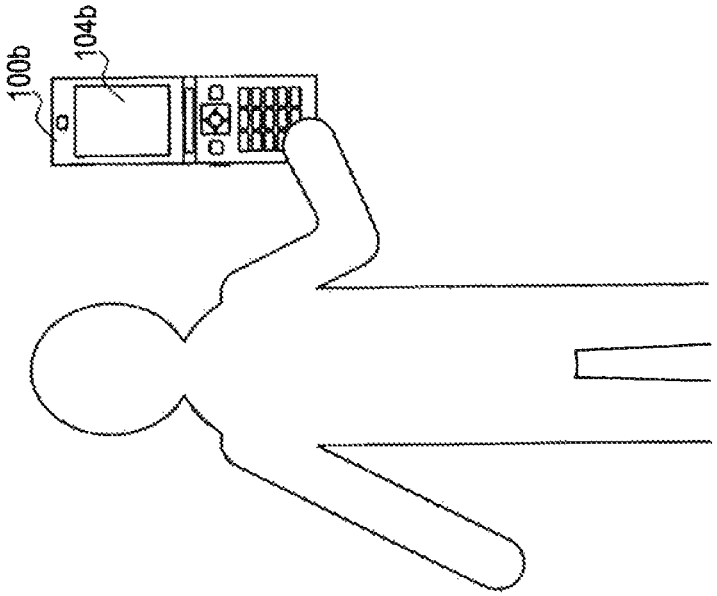


FIG.2A

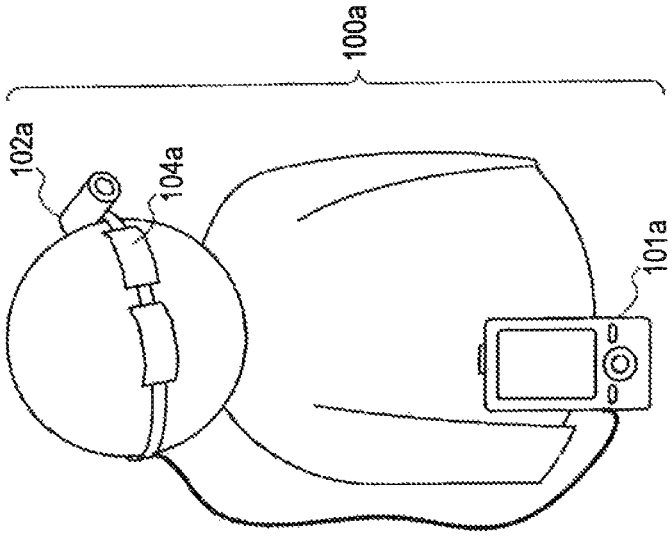


FIG.3A

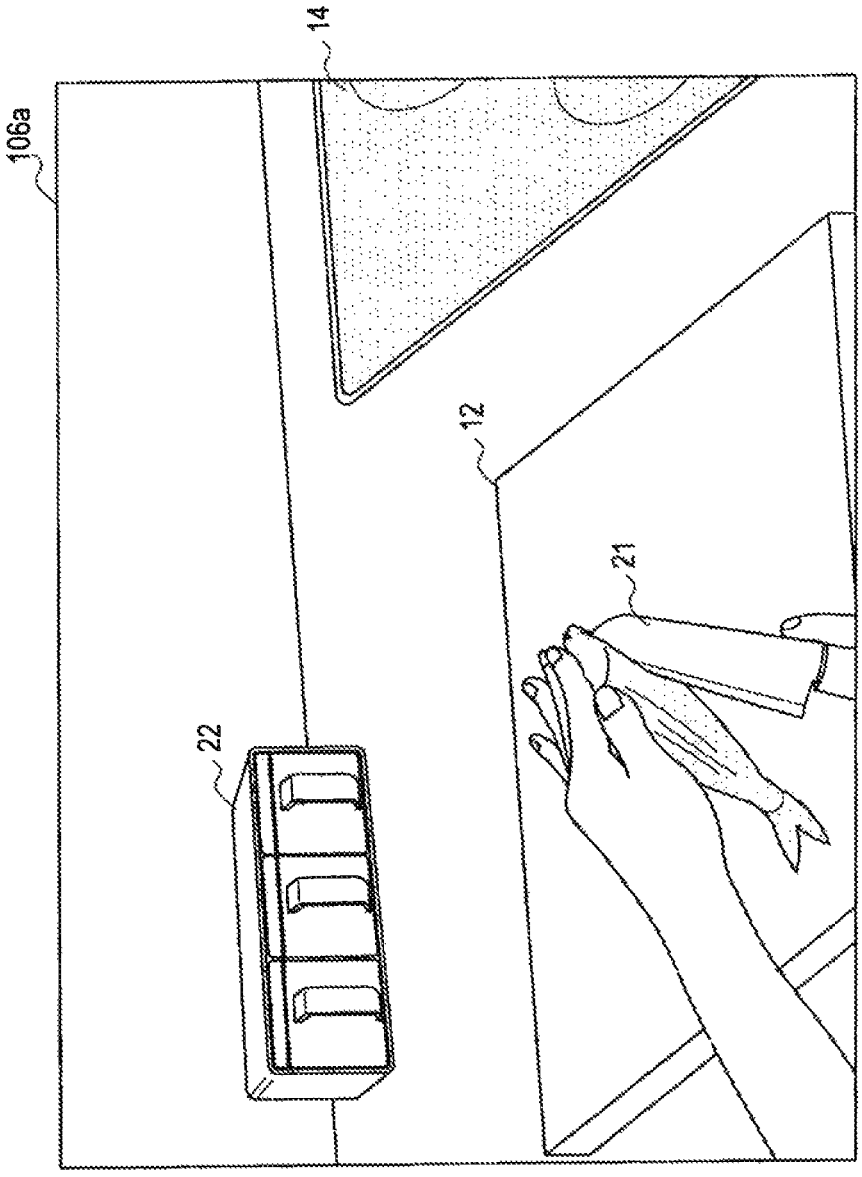


FIG.3B

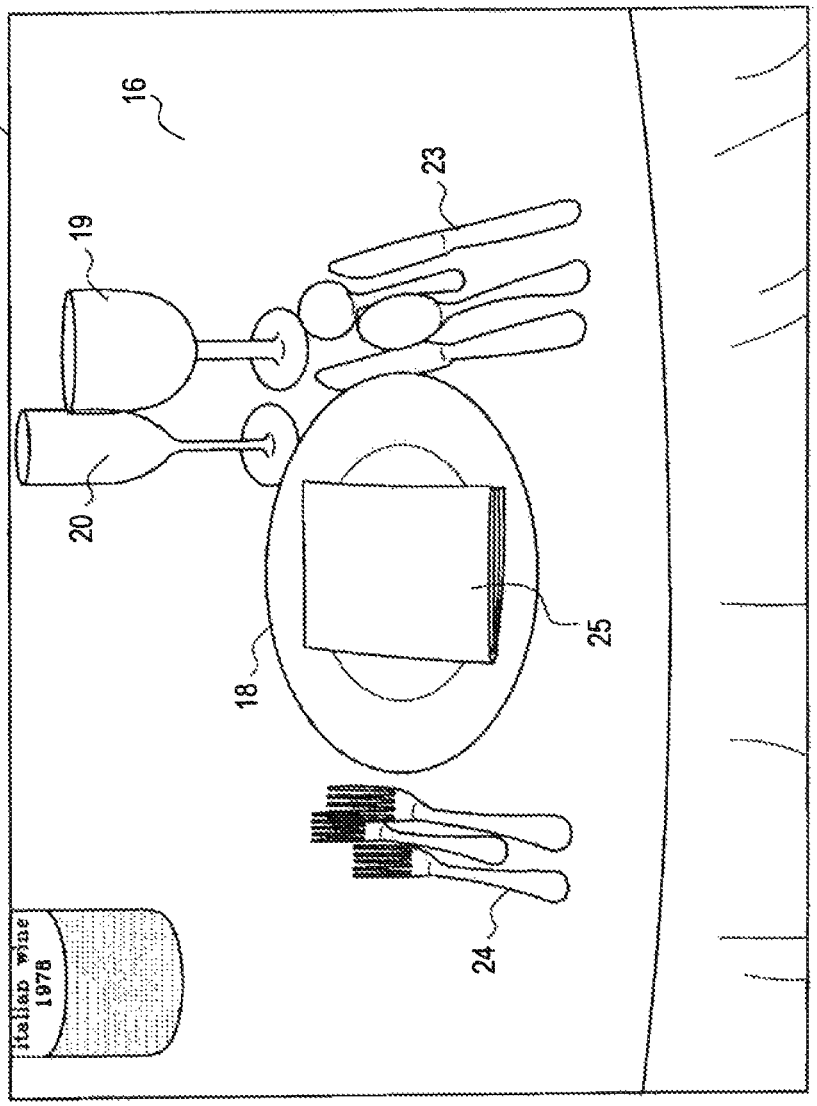


FIG.4

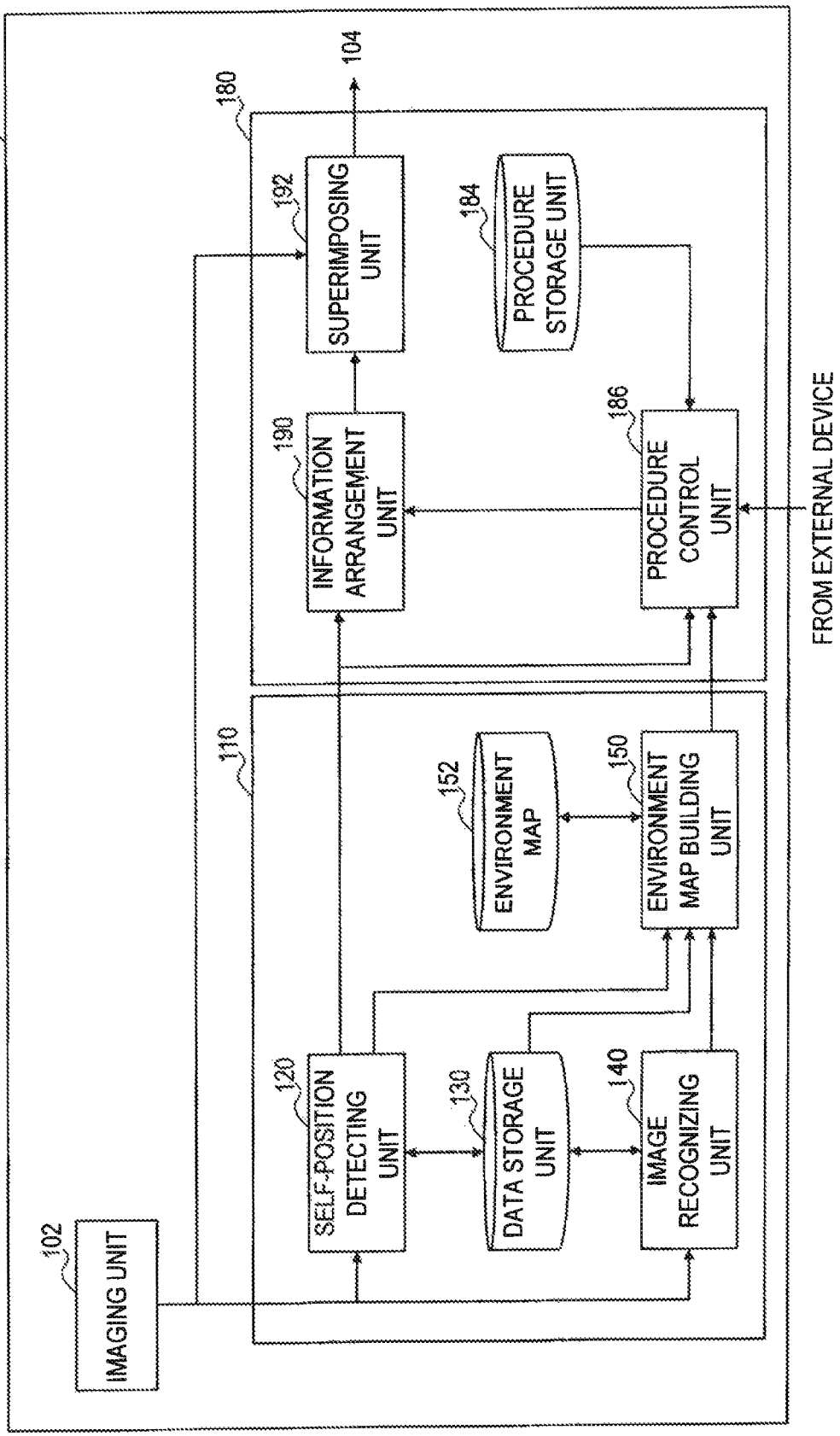

100
104
180
192
SUPERIMPOSING UNIT
184
PROCEDURE STORAGE UNIT
190
INFORMATION ARRANGEMENT UNIT
186
PROCEDURE CONTROL UNIT
FROM EXTERNAL DEVICE
110
152
ENVIRONMENT MAP
150
ENVIRONMENT MAP BUILDING UNIT
120
SELF-POSITION DETECTING UNIT
130
DATA STORAGE UNIT
140
IMAGE RECOGNIZING UNIT
102
IMAGING UNIT

FIG.5

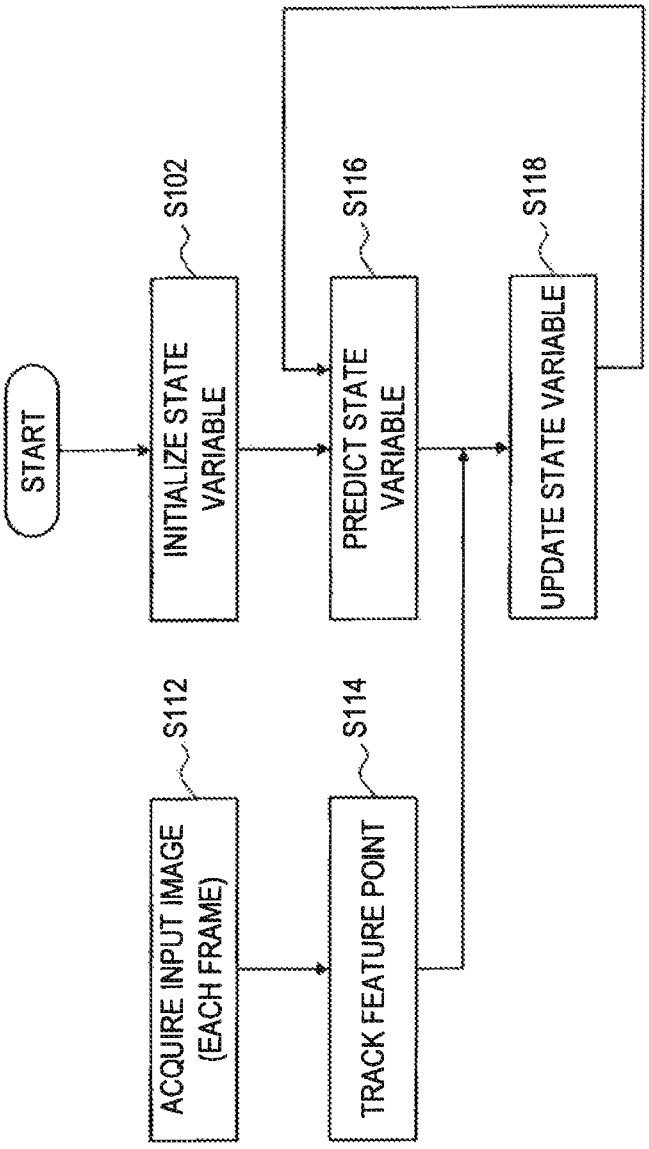

START
INITIALIZE STATE VARIABLE
S102
PREDICT STATE VARIABLE
S116
UPDATE STATE VARIABLE
S118
ACQUIRE INPUT IMAGE (EACH FRAME)
S112
TRACK FEATURE POINT
S114

FIG.6

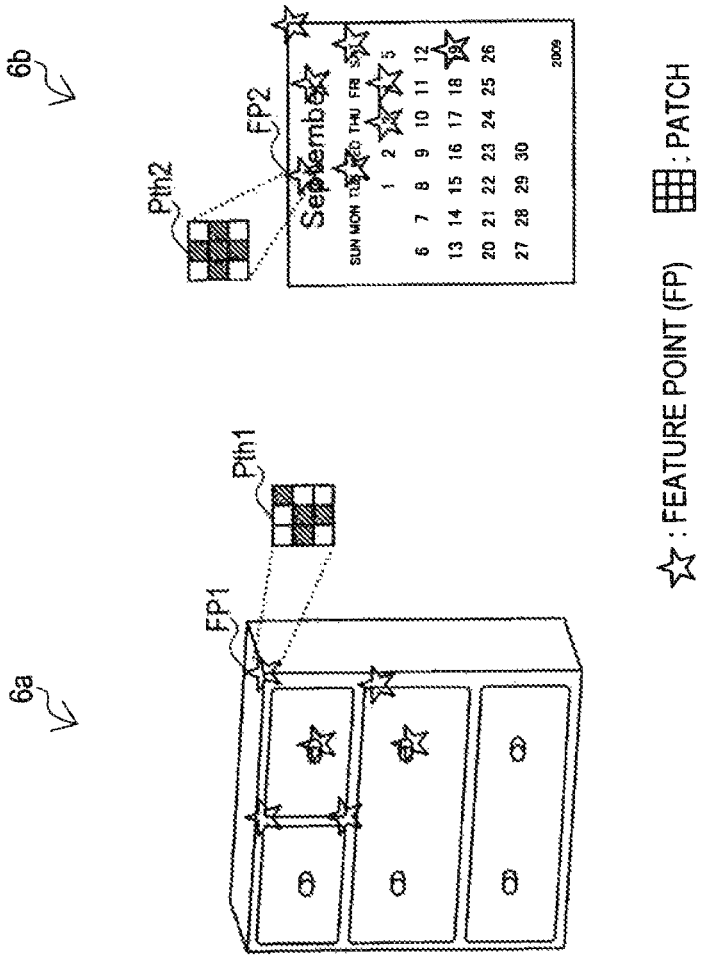

6b
Pth2
FP2
September
2009
6a
Pth1
FP1
☆ : FEATURE POINT (FP)
▦ : PATCH

FIG.7

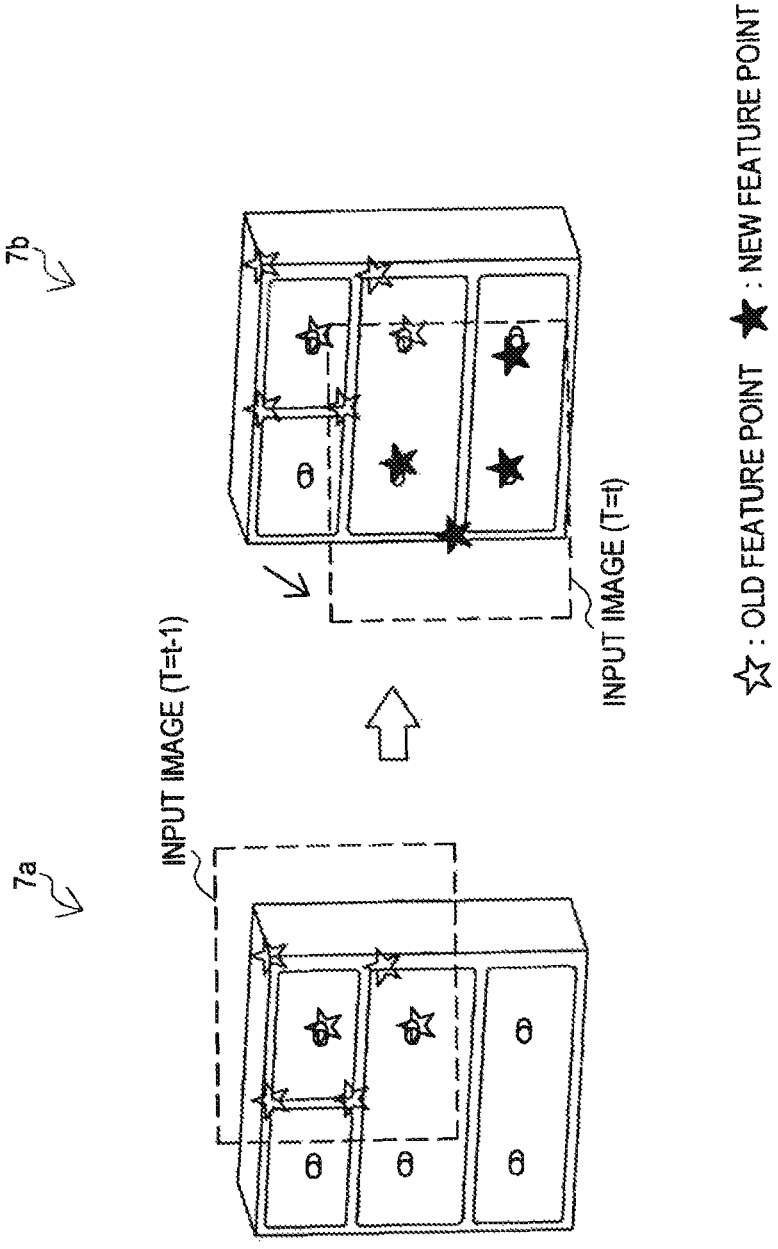

7b
7a
INPUT IMAGE (T=t-1)
INPUT IMAGE (T=t)
☆ : OLD FEATURE POINT ★ : NEW FEATURE POINT

FIG.8

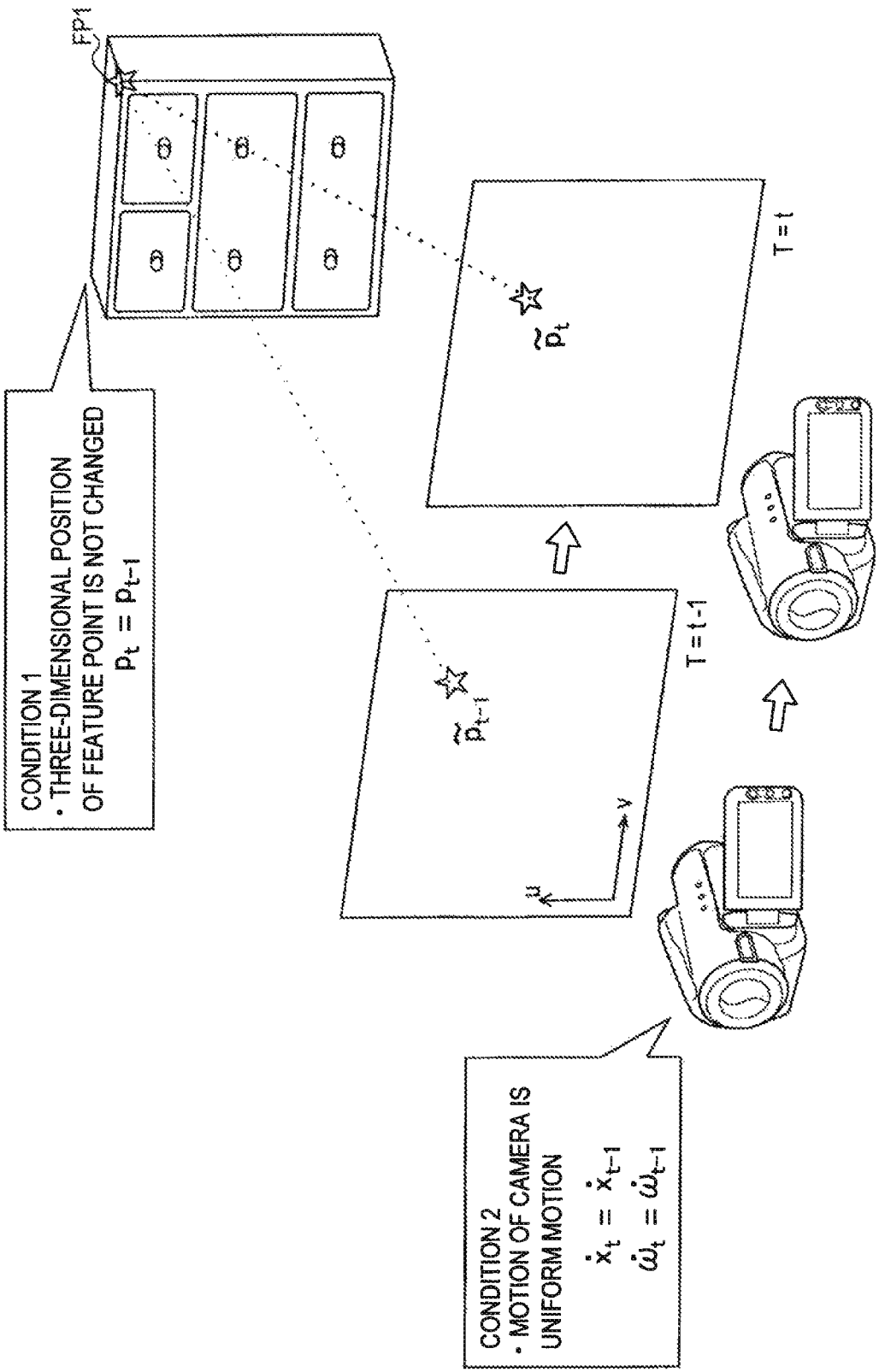

FP1
CONDITION 1
• THREE-DIMENSIONAL POSITION OF FEATURE POINT IS NOT CHANGED
$P_t = P_{t-1}$
$\tilde{p}_t$
T=t
$\tilde{p}_{t-1}$
T=t-1
u
v
CONDITION 2
• MOTION OF CAMERA IS UNIFORM MOTION
$\dot{x}_t = \dot{x}_{t-1}$
$\dot{\omega}_t = \dot{\omega}_{t-1}$

FIG.9

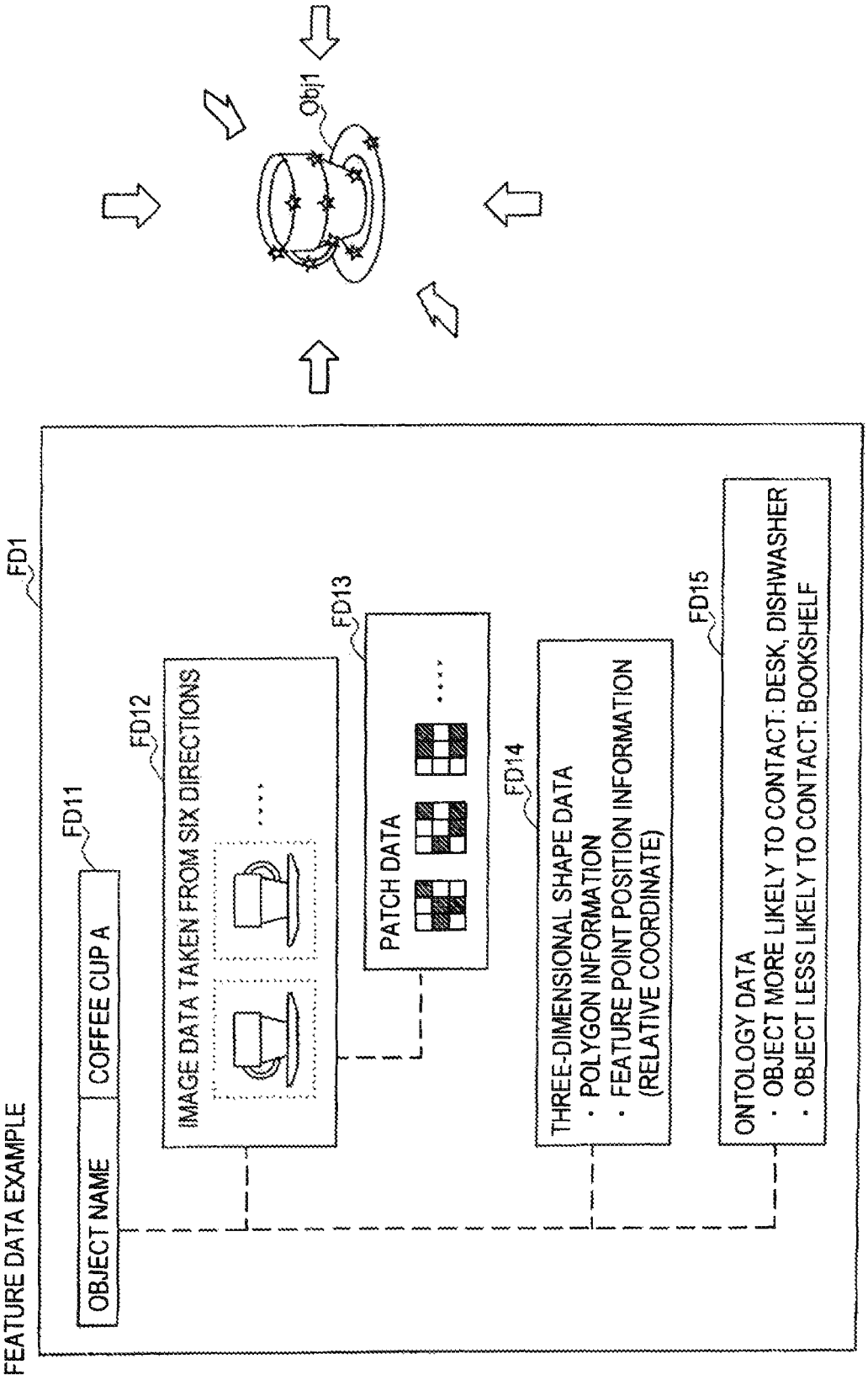

Obj1
FD1
FEATURE DATA EXAMPLE
OBJECT NAME
COFFEE CUP A
FD11
FD12
IMAGE DATA TAKEN FROM SIX DIRECTIONS
FD13
PATCH DATA
FD14
THREE-DIMENSIONAL SHAPE DATA
・POLYGON INFORMATION
・FEATURE POINT POSITION INFORMATION
(RELATIVE COORDINATE)
FD15
ONTOLOGY DATA
・OBJECT MORE LIKELY TO CONTACT: DESK, DISHWASHER
・OBJECT LESS LIKELY TO CONTACT: BOOKSHELF

FIG.10

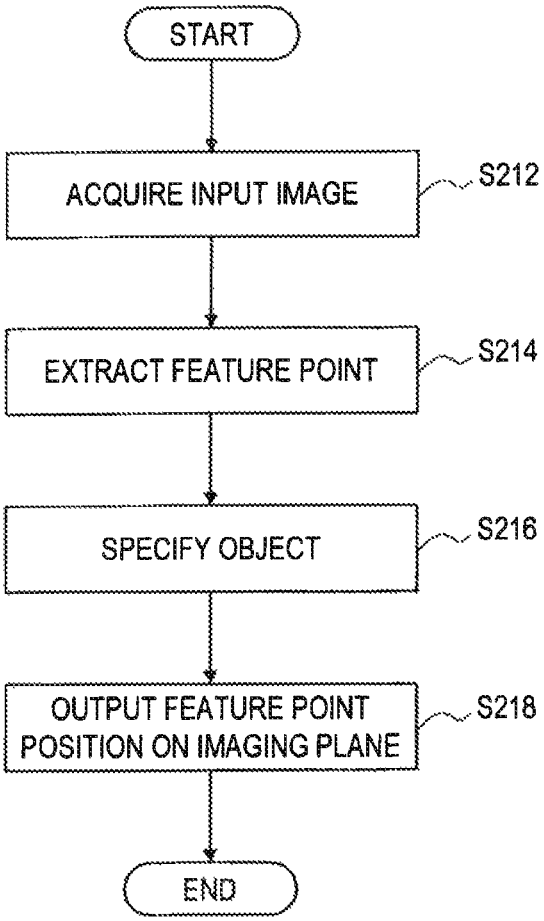

START
ACQUIRE INPUT IMAGE
S212
EXTRACT FEATURE POINT
S214
SPECIFY OBJECT
S216
OUTPUT FEATURE POINT POSITION ON IMAGING PLANE
S218
END

FIG.11

182

NAME OF DIRECTIONS	PROCEDURE ID	PROCEDURE DESCRIPTION	RELATED PHYSICAL OBJECT	PROGRESS CONDITION
TABLE MANNER	P101	SEAT FROM LEFT SIDE OF CHAIR	CHAIR	SEAT
	P102	ORDER FOOD AND DRINK	MENU	MENU IS PUT DOWN
	P103	SET NAPKIN ON YOUR LAP	NAPKIN	NAPKIN IS ON CHAIR
	⋮	⋮	⋮	⋮
FRIED EGG	P201	DIVIDE AND STIR EGGS	BOWL	ONE MINUTE ELAPSES
	P202	FRYING PAN TO STOVE	FRYING PAN	FRYING PAN IS ON STOVE
	P203	PUT THE EGGS ONTO FRYING PAN	STOVE	30 SECONDS ELAPSE FROM STOVE IGNITION
	P204	SPRINKLE SALT AND PEPPER	CRUET	90 SECONDS ELAPSE FROM STOVE IGNITION
	⋮	⋮	⋮	⋮

FIG.12

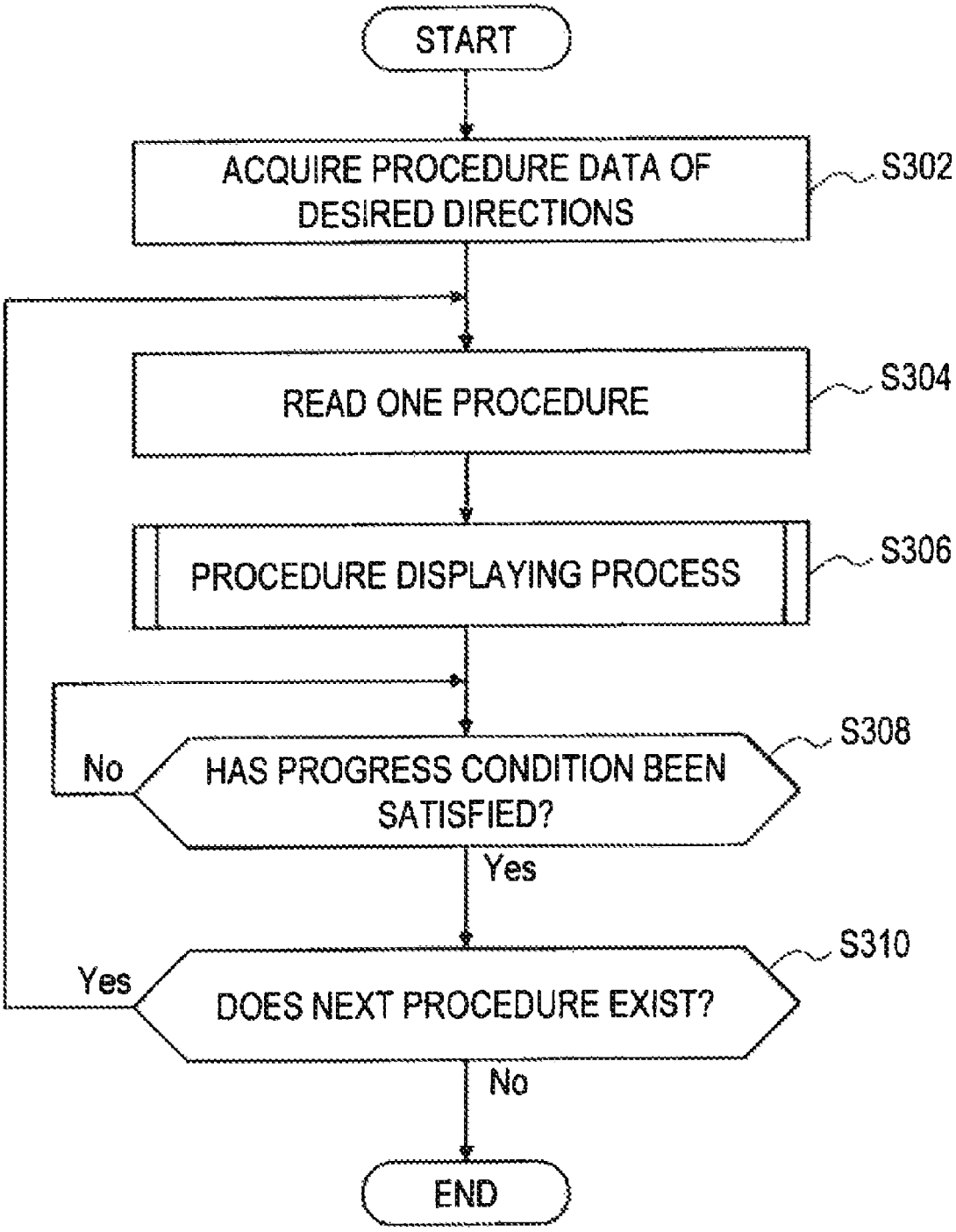

START
ACQUIRE PROCEDURE DATA OF DESIRED DIRECTIONS
S302
READ ONE PROCEDURE
S304
PROCEDURE DISPLAYING PROCESS
S306
No
HAS PROGRESS CONDITION BEEN SATISFIED?
S308
Yes
Yes
DOES NEXT PROCEDURE EXIST?
S310
No
END

FIG.13

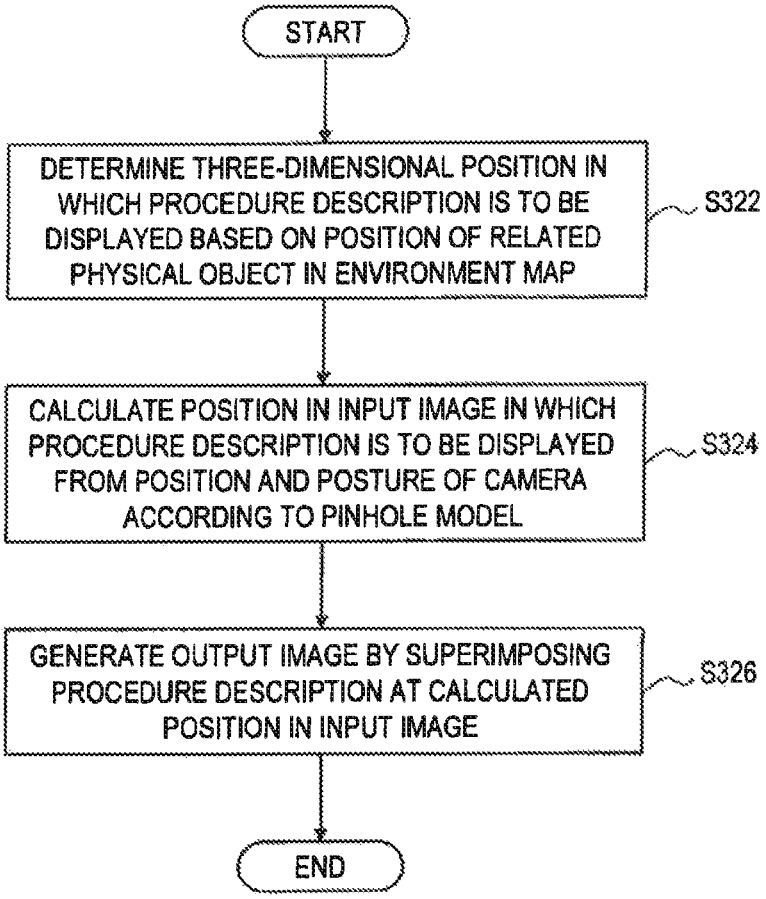

START
DETERMINE THREE-DIMENSIONAL POSITION IN WHICH PROCEDURE DESCRIPTION IS TO BE DISPLAYED BASED ON POSITION OF RELATED PHYSICAL OBJECT IN ENVIRONMENT MAP
S322
CALCULATE POSITION IN INPUT IMAGE IN WHICH PROCEDURE DESCRIPTION IS TO BE DISPLAYED FROM POSITION AND POSTURE OF CAMERA ACCORDING TO PINHOLE MODEL
S324
GENERATE OUTPUT IMAGE BY SUPERIMPOSING PROCEDURE DESCRIPTION AT CALCULATED POSITION IN INPUT IMAGE
S326
END

FIG.14

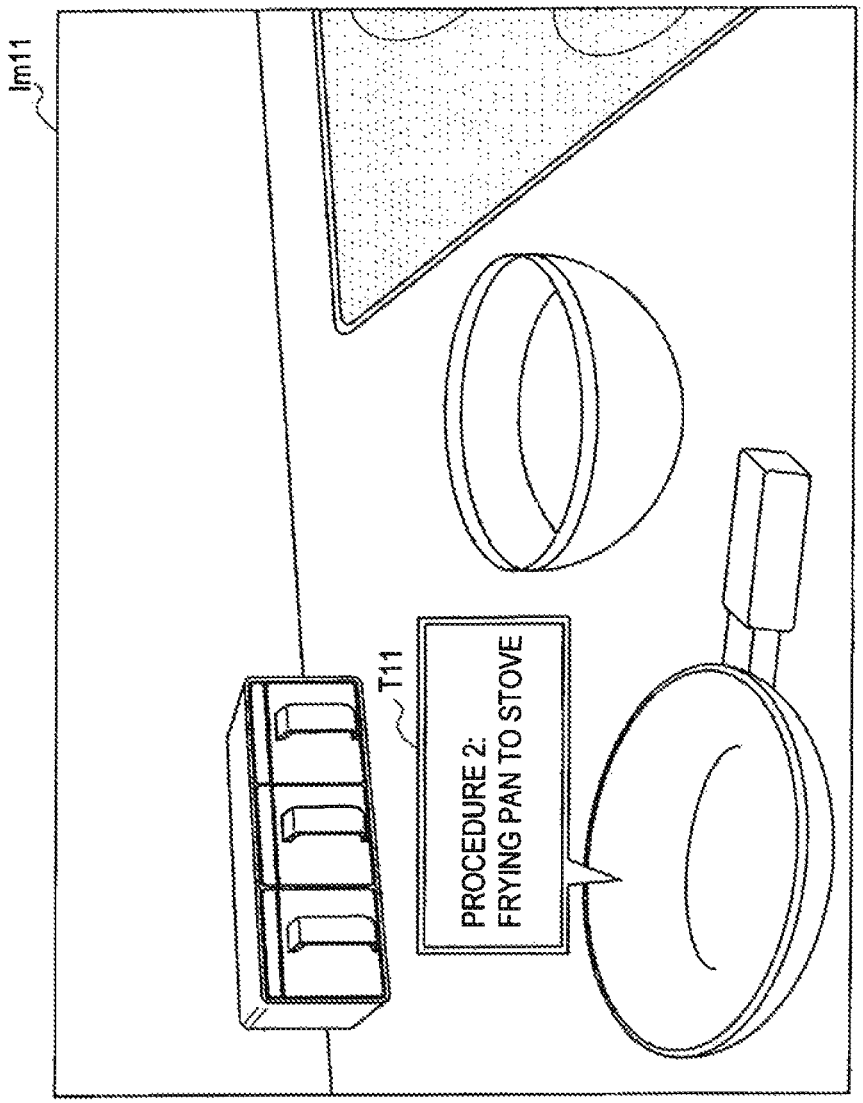


FIG.15

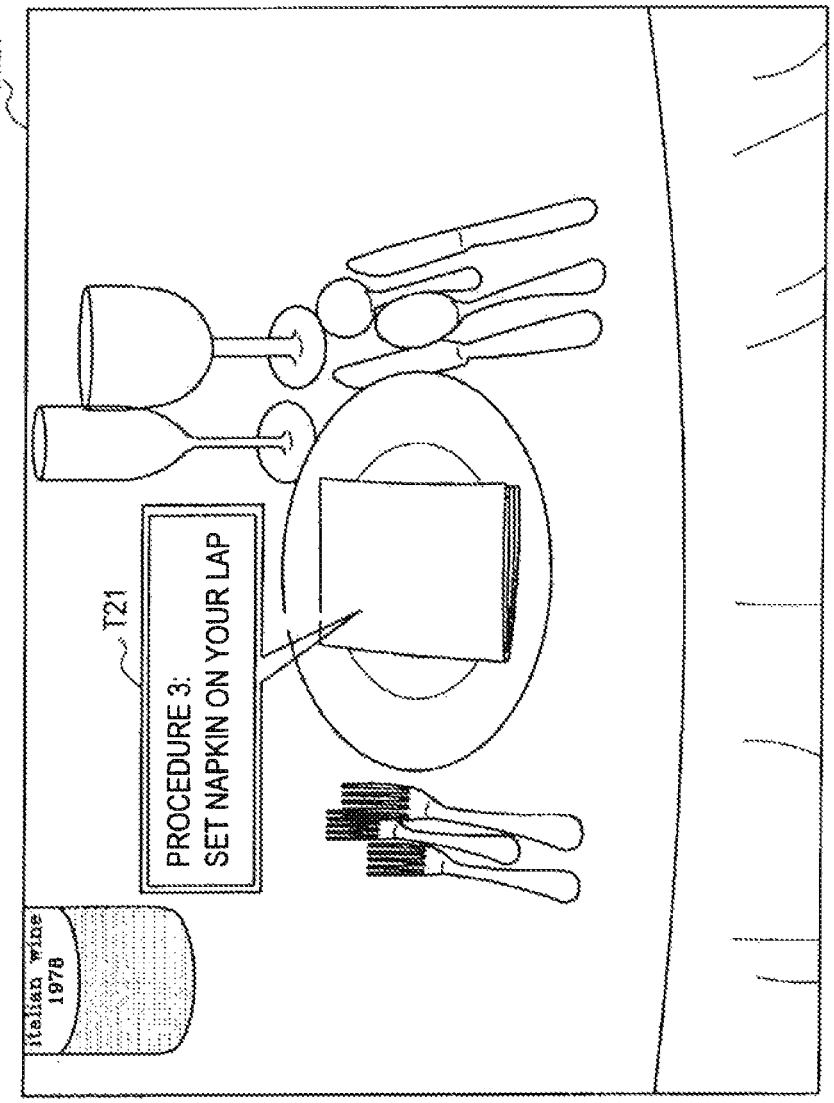

Im21
T21
PROCEDURE 3:
SET NAPKIN ON YOUR LAP
Italian wine
1978

FIG.16

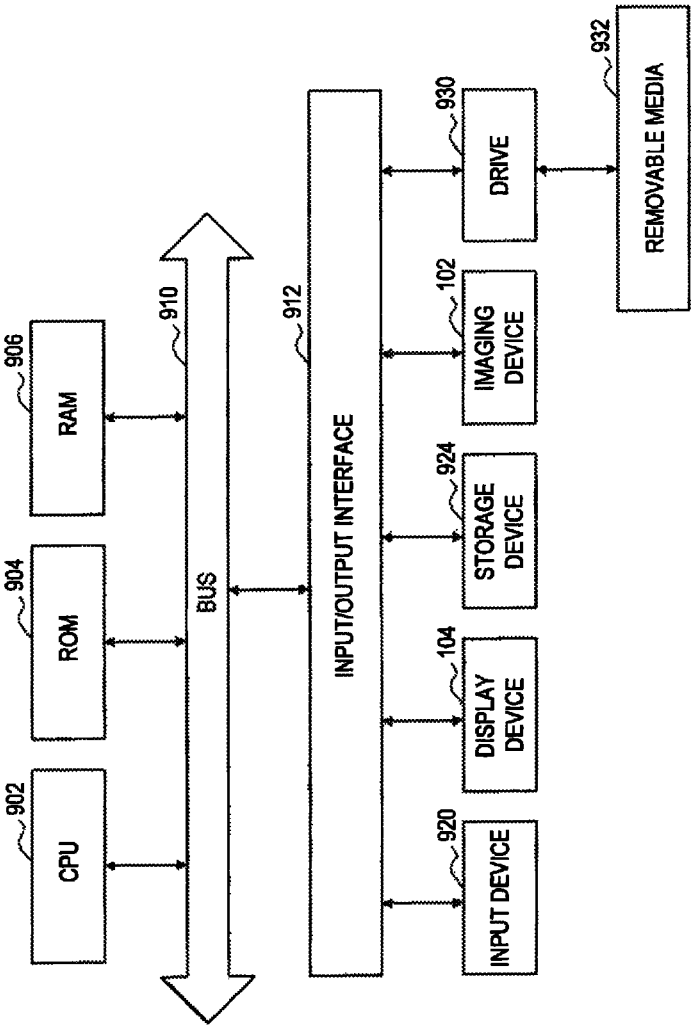

902
CPU
904
ROM
906
RAM
910
BUS
912
INPUT/OUTPUT INTERFACE
920
INPUT DEVICE
104
DISPLAY DEVICE
924
STORAGE DEVICE
102
IMAGING DEVICE
930
DRIVE
932
REMOVABLE MEDIA

IMAGE PROCESSING DEVICE, IMAGE PROCESSING METHOD, AND PROGRAM

CROSS REFERENCE TO PRIOR APPLICATION

This application is a continuation of U.S. patent application Ser. No. 12/984,847 (filed on Jan. 5, 2011), which claims priority to Japanese Patent Application No. 2010-021368 (filed on Feb. 2, 2010), which are all hereby incorporated by reference in their entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an image processing device, an image processing method, and a program.

2. Description of the Related Art

Recently, technology called augmented reality (AR) in which an image obtained by imaging a real space is processed and then presented to a user has been receiving attention. In the AR technology, useful information related to a physical object in a real space present in an input image may be inserted into the image and output as an output image, for example. That is, in the AR technology, typically, a large part of the image presented to the user shows the real space, and a part of the image may be processed in accordance with a purpose. Such a characteristic contrasts it with virtual reality in which an entire (or a large part) of the output image is composed using computer graphics (CG). By using the AR technology, for example, advantages such as easy recognition of a situation of the real space by a user or operation support based on the output image may be provided.

In the AR technology, in order to present actually useful information to the user, it is important that a computer accurately recognize a situation of the real space. Therefore, technology aimed at recognizing the situation of the real space, which serves as a basis of the AR technology, has been developed. For example, Japanese Patent Application Laid-Open Publication No. 2008-304268 discloses a method of dynamically generating an environment map representing a three-dimensional position of physical objects existing in a real space by applying technology called simultaneous localization and mapping (SLAM) capable of simultaneously estimating a position and a posture of a camera and a position of a feature point shown in an image of the camera. Further, a basic principle of the SLAM technology using a monocular camera is disclosed in Andrew J. Davison's, "Real-Time Simultaneous Localization and Mapping with a Single Camera," Proceedings of the 9th IEEE International Conference on Computer Vision Volume 2, 2003, pp. 1403-1410.

Now, information terminals capable of performing enhanced information processing are widely used and users use the information terminals to view various information. An example of the information includes directions. For example, various information, such as table manners, a cooking procedure, a method of manipulating or repairing electrical appliances, or the like, as well as directions of electronic devices, describing a procedure of an operation to be performed in a real space are made in an electronic form and provided to the users via web pages or other applications.

SUMMARY OF THE INVENTION

However, existing electronic directions are generally described based on the premise that the electronic directions are displayed on a two-dimensional screen, like paper directions. Accordingly, some information about positions of operation in a three-dimensional real space is missed, often making it difficult for a user to intuitively understand a procedure of the operation. In particular, for an operation in a real space in which an environment surrounding a user may be dynamically changed, such environment is not described in the directions, making it more difficult to understand the directions.

Accordingly, if an environment map three-dimensionally representing an environment surrounding a user can be dynamically built and a direction for each procedure of the operation can be displayed in a position associated with the environment map, the operation procedure is expected to be intuitively and easily understood by the user.

In light of the foregoing, it is desirable to provide an image processing device, an image processing method, and a program which allow an operation procedure performed in a real space to be intuitively and easily understood by applying an environment map.

According to an embodiment of the present invention, there is provided an image processing device including: a data storage unit having feature data stored therein, the feature data indicating a feature of appearance of one or more physical objects; an environment map building unit for building an environment map based on an input image obtained by imaging a real space using an imaging device and the feature data stored in the data storage unit, the environment map representing a position of a physical object present in the real space; a control unit for acquiring procedure data for a set of procedures of operation to be performed in the real space, the procedure data defining a correspondence between a direction for each procedure and position information designating a position at which the direction is to be displayed; and a superimposing unit for generating an output image by superimposing the direction for each procedure included in the set of procedures at a position in the input image determined based on the environment map and the position information, using the procedure data acquired by the control unit.

According to such a configuration, the direction for each procedure included in a set of procedures of operation to be performed in the real space is superimposed at a position in the input image determined based on the environment map three-dimensionally representing positions of physical objects present in the real space, according to definition by procedure data.

The position information may designate a position in the environment map at which the direction is to be displayed, by specifying a physical object related to the direction for each procedure.

The procedure data may define a further correspondence between the direction for each procedure and a condition for progressing displaying of each direction.

The condition for progressing displaying of each direction may include a condition according to a position or a posture of a physical object represented by the environment map.

The control unit may control displaying of the direction for each procedure included in the set of procedures according to the procedure data.

The image processing device may further include a detection unit for dynamically detecting a position in the real space of the imaging device based on the input image and the feature data, and the position in the input image at which the direction for each procedure is to be superimposed may be determined according to the position in the real space of the imaging device detected by the detection unit.

According to another embodiment of the present invention, there is provided an image processing method in an image processing device including a storage medium having feature

data stored therein, the feature data indicating a feature of appearance of one or more physical objects, the method including the steps of: acquiring an input image obtained by imaging a real space using an imaging device; building an environment map based on the input image and the feature data, the environment map representing a position of a physical object present in the real space; acquiring procedure data for a set of procedures of operation to be performed in the real space, the procedure data defining a correspondence between a direction for each procedure and position information designating a position at which the direction is to be displayed; and generating an output image by superimposing the direction for each procedure included in the set of procedures at a position in the input image determined based on the environment map and the position information, using the acquired procedure data.

According to another embodiment of the present invention, there is provided a program for causing a computer, which controls an image processing device including a storage medium having feature data stored therein, the feature data indicating a feature of appearance of one or more physical objects, to function as: an environment map building unit for building an environment map based on an input image obtained by imaging a real space using an imaging device and the feature data, the environment map representing a position of a physical object present in the real space; a control unit for acquiring procedure data for a set of procedures of operation to be performed in the real space, the procedure data defining a correspondence between a direction for each procedure and position information designating a position at which the direction is to be displayed; and a superimposing unit for generating an output image by superimposing the direction for each procedure included in the set of procedures at a position in the input image determined based on the environment map and the position information, using the procedure data acquired by the control unit.

As described above, according to an image processing device, an image processing method, and a program in an embodiment of the present invention, it is possible to enable an operation procedure performed in the real space to be intuitively and easily understood by applying the environment map.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A is a schematic diagram showing a first example of an environment in which an image processing device can be used according to an embodiment;

FIG. **1**B is a schematic diagram showing a second example of the environment in which the image processing device can be used according to the embodiment;

FIG. **2**A is a first illustrative diagram for illustrating an image processing device according to an embodiment;

FIG. **2**B is a second illustrative diagram for illustrating an image processing device according to an embodiment;

FIG. **3**A is an illustrative diagram showing an example of an input image that can be acquired in a real environment shown in FIG. **1**A;

FIG. **3**B is an illustrative diagram showing an example of an input image that can be acquired in a real environment shown in FIG. **1**B;

FIG. **4** is a block diagram showing an example of a configuration of an image processing device according to an embodiment;

FIG. **5** is a flowchart showing an example of flow of a self-position detection process according to an embodiment;

FIG. **6** is an illustrative diagram for illustrating a feature point set on an object;

FIG. **7** is an illustrative diagram for illustrating addition of feature points;

FIG. **8** is an illustrative diagram for illustrating an example of a prediction model;

FIG. **9** is an illustrative diagram for illustrating an example of a configuration of feature data;

FIG. **10** is a flowchart showing an example of flow of an object recognition process according to an embodiment;

FIG. **11** an illustrative diagram for illustrating an example of procedure data that can be acquired in an embodiment;

FIG. **12** is a flowchart showing an example of flow of a procedure control process according to an embodiment;

FIG. **13** is a flowchart showing an example of flow of a procedure displaying process according to an embodiment;

FIG. **14** is an illustrative diagram showing a first example of an output image output by an image processing device according to an embodiment;

FIG. **15** is an illustrative diagram showing a second example of an output image output by an image processing device according to an embodiment; and

FIG. **16** is a block diagram showing an example of a hardware configuration of a general-purpose computer.

DETAILED DESCRIPTION OF THE EMBODIMENT(S)

Hereinafter, preferred embodiments of the present invention will be described in detail with reference to the appended drawings. Note that, in this specification and the appended drawings, structural elements that have substantially the same function and structure are denoted with the same reference numerals, and repeated explanation of these structural elements is omitted,

Also, the "detailed description of the embodiment(s)" will be described in the following order.

1. Overview of Image Processing Device
2. Configuration of Image Processing Device according to Embodiment
2-1. Imaging unit
2-2. Environment Map Generating Unit
2-3. Output Image Generating Unit
2-4. Example of Output Image
3. Example of Hardware Configuration
4. Conclusion

1. OVERVIEW OF IMAGE PROCESSING DEVICE

First, an overview of an image processing device according to an embodiment of the present invention will be described with reference to FIGS. **1**A to **3**B. FIGS. **1**A and **1**B show environments **1***a* and **1***b*, for example, in which the image processing device **100** according to an embodiment of the present invention can be used, respectively.

Referring to FIG. **1**A, a sink **11**, a cutting board **12**, a bowl **13**, a stove **14**, a microwave oven **15**, and other physical objects are present in the environment **1***a*. That is, the environment **1***a* is an environment corresponding to a kitchen as a real space where a user prepares food. Meanwhile, referring to FIG. **1**B, a table **16**, chairs **17**, dishes **18**, glasses **19** and **20**, and other physical objects are present in an environment **1***b*. That is, the environment **1***b* is an environment corresponding to a dining room (or guest seating of a restaurant) as a real space where a user dines.

FIGS. **2**A and **2**B are illustrative diagrams for illustrating an image processing device **100** that may be used inside the environment **1***a* or **1***b*, for example, as described above.

Referring to FIG. **2**A, an image processing device **100***a* including a body **101***a*, an imaging device **102***a* and a display device **104***a*, which are mounted to a user, is shown. The body **101***a* includes a central processing unit (CPU) for executing image processing in the image processing device **100**, which will be described in detail later, a storage medium, and the like. The imaging device **102***a* is mounted to a head portion of the user in the same direction as a user's gaze, to image the inside of the environment **1***a* or **1***b* to generate a set of input images. The image processing device **100***a* executes image processing using the set of input images generated by the imaging device **102***a* as an input to generate a set of output images. The output images generated by the image processing device **100***a* are displayed by the display device **104***a*. The display device **104***a* is a head mount display mounted to the head portion of the user. The display device **104***a* may be, for example, a see-through display.

Referring to FIG. **2**B, an image processing device **100***b* such as a mobile phone terminal held by the user is shown. The image processing device **100***b* is, for example, a mobile phone terminal with an imaging device, and includes an imaging device (e.g., provided at the rear of a display device **104***b*) and the display device **104***b*. The image processing device **100***b* includes a CPU for executing image processing in the image processing device **100**, which will be described in detail later, a storage medium, and the like.

In this disclosure, when the image processing devices **100***a* and **100***b* need not be discriminated from each other, letters of the reference numerals are omitted to collectively refer to the image processing devices **100***a* and **100***b* as the image processing device **100**. Also, the same applies to the imaging devices **102***a* and **102***b* (imaging device **102**), the display devices **104***a* and **104***b* (display device **104**) and other elements.

FIGS. **3**A and **3**B are illustrative diagrams showing input images **106***a* and **106***b*, for example, acquired by the imaging device **102** imaging the environments **1***a* and **1***b*, respectively.

Referring to FIG. **3**A, a cutting board **12**, a stove **14**, a kitchen knife **21**, a cruet **22** and other physical objects are shown in the input image **106***a*. The input image **106***a* is the same image as an image shown in the vision of the user preparing food in the environment **1***a*. The image processing device **100** acquires a set of input images including such an input image **106***a*, for example, using the imaging device **102**, and superimposes a direction for a cooking procedure on each input image.

Referring to FIG. **3**B, a table **16**, a dish **18**, glasses **19** and **20**, a knife **23**, forks **24**, a napkin **25** and other physical objects are shown in an input image **106***b*. The input image **106***b* is the same image as an image shown in the vision of a user dining in the environment **1***b*. The image processing device **100** acquires a set of input images including such an input image **106***b*, for example, using the imaging device **102** and superimposes a direction for table manners during the meal on each input image.

An example of a configuration of such an image processing device **10** be described in greater detail in the next section.

2. CONFIGURATION OF IMAGE PROCESSING DEVICE ACCORDING TO EMBODIMENT

FIG. **4** is a block diagram showing an example of a configuration of the image processing device **100** according to an embodiment of the present invention. Referring to FIG. **4**, the image processing device **100** includes an imaging unit **102**, an environment map generating unit **110**, and an output image generating unit **180**.

[2-1. Imaging Unit]

The imaging unit **102** may be realized as an imaging device having an imaging element such as a charge coupled device (CCD) or a complementary metal oxide semiconductor (CMOS), for example. The imaging unit **102** may be provided outside the image processing device **100**. The imaging unit **102** outputs an image acquired by imaging the real space such as the environment **1***a* or the environment **1***b* to the environment map generating unit **110** and the output image generating unit **180** as the input image.

[2-2. Environment Map Generating Unit]

The environment map generating unit **110** generates an environment map representing, for example, positions of one or more physical objects present in the real space based on the input image input from the imaging unit **102** and feature data of an object, which will be described later, stored in a data storage unit **130**. As shown in FIG. **4**, in this embodiment, the environment map generating unit **110** includes a self-position detecting unit **120**, the data storage unit **130**, an image recognizing unit **140**, an environment map building unit **150** and an environment map storage unit **152**.

(1) Self-Position Detection Unit

The self-position detecting unit **120** dynamically detects a position of the imaging device, which takes the input image, based on the input image input from the imaging unit **102** and the feature data stored in the data storage unit **130**. For example, even in a case in which the imaging device has a monocular camera, the self-position detecting unit **120** may dynamically determine a position and posture of the camera and a position of a feature point (FP) on an imaging plane of the camera for each frame by applying the SLAM technology disclosed in Andrew J. Davison's "Real-Time Simultaneous Localization and Mapping with a Single Camera," Proceedings of the 9th IEEE International Conference on Computer Vision Volume 2, 2003, pp. 1403-1410.

First, entire flow of a self-position detection process in the self-position detecting unit **120** to which the SLAM technology is applied will be described with reference to FIG. **5**. Next, the self-position detection process will be described in detail with reference to FIGS. **6** to **8**.

FIG. **5** is a flowchart showing an example of the flow of the self-position detection process in the self-position detecting unit **120** to which the SLAM technology is applied. In FIG. **5**, when the self-position detection process starts, the self-position detecting unit **120** first initializes a state variable (step S**102**). In this embodiment, the state variable is a vector including the position and the posture (rotation angle) of the camera, a moving speed and an angular speed of the camera and the position of one or more FPs as elements. The self-position detecting unit **120** then sequentially obtains the input image from the imaging unit **102** (step S**112**). The process from step S**112** to step S**118** may be repeated for each input image (i.e., each frame).

In step S**114**, the self-position detecting unit **120** tracks FPs present in the input image. For example, the self-position detecting unit **120** detects a patch (small image of 3×3=9 pixels around a FP, for example) of each FP stored in advance in the data storage unit **130** from the input image. The position of the patch detected herein, that is, the position of the FP, is used to update the state variable later.

In step S116, the self-position detecting unit **120** generates, for example, a predicted value of the state variable of a next frame based on a given prediction model. Also, in step S118, the self-position detecting unit **120** updates the state variable using the predicted value of the state variable generated in step S116 and an observed value according to the position of the FP detected in step S114. The self-position detecting unit **120** executes the process in steps S116 and S118 based on a principle of an extended Kalman filter.

As a result of such a process, a value of the state variable updated for each frame is output. Hereinafter, contents of respective processes of tracking the FP (step S114), prediction of the state variable (step S116) and updating the state variable (step S118) will be described more specifically.

(1-1) Tracking of FP

In this embodiment, the data storage unit **130** stores the feature data indicating features of objects corresponding to physical objects which may be present in the real space, in advance. The feature data includes small images, that is, the patches regarding one or more FPs, each representing the feature of appearance of each object, for example. The patch may be the small image composed of 3×3=9 pixels around the FP, for example.

FIG. **6** shows two examples of the objects and an example of FPs and patches set on each object. A left object in FIG. **6** is the object representing a drawer (see FIG. **6***a*). A plurality of FPs including a feature point FP**1** are set on the object. Further, a patch Pth**1** is defined to be associated with the feature point FP**1**. On the other hand, a right object in FIG. **6** is the object representing a calendar (see FIG. **6***b*). A plurality of FPs including a feature point FP**2** are set on the object. Further, a patch Pth**2** is defined to be associated with the feature point FP**2**.

When the input image is acquired from the imaging unit **102**, the self-position detecting unit **120** matches partial images included in the input image against the patch for each FP illustrated in FIG. **6** stored in advance in the data storage unit **130**. The self-position detecting unit **120** then specifies a position of each FP included in the input image (a position of a center pixel of the detected patch, for example) as the result of matching.

Further, in tracking of the FPs (step S114 in FIG. **5**), data regarding all the FPs to be tracked may not be stored in the data storage unit **130** in advance. For example, six FPs are detected in the input image at time T=t−1 in an example of FIG. **7** (see FIG. **7***a*). Next, when the position or the posture of the camera changes at time T=t, only two of the six FPs present in the input image at the time T=t−1 are present in the input image. In this case, the self-position detecting unit **120** may newly set FPs in positions where a characteristic pixel pattern of the input image is present and use the new FPs in the self-position detection process for a subsequent frame. For example, in the example shown in FIG. **7**, four new FPs are set on the object at the time T=t (see FIG. **7***b*). This is a characteristic of the SLAM technology, and accordingly, a cost of setting all of the FPs in advance can be reduced and accuracy of the process can be improved using a number of added FPs.

(1-2) Prediction of State Variable

In this embodiment, the self-position detecting unit **120** uses a state variable X shown in the following equation as the state variable to be applied with the extended Kalman filter.

[Equation 1]

$$X = \begin{pmatrix} x \\ \omega \\ \dot{x} \\ \dot{\omega} \\ p_1 \\ \vdots \\ p_N \end{pmatrix} \tag{1}$$

The first element of the state variable X in Equation (1) represents a three-dimensional position of the camera in a global coordinate system (x, y, z) being a coordinate system set in the real space, as in the following equation.

[Equation 2]

$$x = \begin{pmatrix} x_c \\ y_c \\ z_c \end{pmatrix} \tag{2}$$

Also, the second element of the state variable is a four-dimensional vector ω having a quaternion as an element corresponding to a rotation matrix representing the posture of the camera. The posture of the camera may be represented using an Euler angle in place of the quaternion. Also, the third and the fourth elements of the state variable represent the moving speed and the angular speed of the camera, respectively.

Further, the fifth and subsequent elements of the state variable represent a three-dimensional position p_i of a FP FP_i (i= 1 . . . N) in the global coordinate system as shown in a following equation. Further, as described above, the number N of the FPs may change during the process.

[Equation 3]

$$p_i = \begin{pmatrix} x_i \\ y_i \\ z_i \end{pmatrix} \tag{3}$$

The self-position detecting unit **120** generates the predicted value of the state variable for a latest frame based on the value of the state variable X initialized in step S102 or the value of the state variable X updated in a previous frame. The predicted value of the state variable is generated according to a state equation of the extended Kalman filter according to multi-dimensional normal distribution shown in the following equation.

[Equation 4]

$$\text{predicted state variable } \hat{X} = F(X, a) + w \tag{4}$$

Here, F denotes the prediction model regarding state transition of a system. a denotes a prediction condition. Also, w denotes Gaussian noise and may include a model approximation error, an observation error and the like, for example. In general, an average of the Gaussian noise w is 0.

FIG. **8** is an illustrative diagram for illustrating an example of the prediction model according to this embodiment. Referring to FIG. **8**, two prediction conditions in the prediction model according to this embodiment are shown. First, as a

first condition, it is assumed that the three-dimensional position of the FP in the global coordinate system does not change. That is, provided that the three-dimensional position of the FP FP**1** at the time T is p_T, the following relationship is satisfied.

[Equation 5]

$$p_t=p_{t-1} \tag{5}$$

Next, as a second condition, it is assumed that motion of the camera is uniform motion. That is, a following relationship is satisfied for the speed and the angular speed of the camera from the time T=t−1 to the time T=t.

[Equation 6]

$$\dot{x}_t=\dot{x}_{t-1} \tag{6}$$

$$\dot{\omega}_t=\dot{\omega}_{t-1} \tag{7}$$

The self-position detecting unit **120** generates the predicted value of the state variable for the latest frame based on such a prediction model and the state equation expressed in Equation (4).

(1-3) Updating of State Variable

The self-position detecting unit **120** then evaluates an error between observation information predicted from the predicted value of the state variable and actual observation information obtained as a result of FP tracking, using an observation equation, for example. Note that v in Equation (8) is the error.

[Equation 7]

$$\text{observation information } s=H(\hat{X})+v \tag{8}$$

$$\text{predicted observation information } \hat{s}=H(\hat{X}) \tag{9}$$

Here, H represents an observation model. For example, a position of the FP FP_i on the imaging plane (u-v plane) is defined as expressed in the following equation.

[Equation 8]

$$\text{position of } FP_i \text{ on imaging plane } \tilde{p}_i=\begin{pmatrix} u_i \\ v_i \\ 1 \end{pmatrix} \tag{10}$$

Here, all of the position of the camera x, the posture of the camera ω and the three-dimensional position p_i of the FP FP_i are given as the elements of the state variable X. Then, the position of the FP FP_i on the imaging plane is derived using the following equation according to a pinhole model.

[Equation 9]

$$\lambda\tilde{p}_i=AR_\omega(p_i-x) \tag{11}$$

Herein, λ represents a parameter for normalization, A represents a camera internal parameter, R_ω represents the rotation matrix corresponding to the quaternion ω representing the posture of the camera included in the state variable X. The camera internal parameter A is given in advance as expressed in the following equation according to characteristics of the imaging device, which takes the input image.

[Equation 10]

$$A=\begin{pmatrix} -f\cdot k_u & f\cdot k_u\cdot\cot\theta & u_o \\ 0 & -\frac{f\cdot k_v}{\sin\theta} & v_o \\ 0 & 0 & 1 \end{pmatrix} \tag{12}$$

Herein, f represents focal distance, θ represents orthogonality of an image axis (ideal value is 90 degrees), k_u represents a scale along a vertical axis of the imaging plane (rate of change of scale from the global coordinate system to the coordinate system of the imaging plane), k_v represents a scale along a horizontal axis of the imaging plane, and (u_o, v_o) represents a center position of the imaging plane.

Therefore, a feasible latest state variable X may be obtained by searching the state variable X, which makes the error between the predicted observation information derived using Equation (11), that is, the position of each FP on the imaging plane and the result of FP tracking in step S**114** in FIG. **5**, minimum.

[Equation 11]

$$\text{lastest state variable } X\leftarrow\hat{X}+\text{Innov}(s-\hat{s}) \tag{13}$$

The self-position detecting unit **120** outputs the position x and the posture ω of the camera (imaging device) dynamically updated by applying the SLAM technology in this manner to the environment map building unit **150** and the output image generating unit **180**.

(2) Data Storage Unit

The data storage unit **130** stores in advance the feature data indicating the feature of the object corresponding to the physical object, which may be present in the real space, using a storage medium such as a hard disk or a semiconductor memory. Although an example in which the data storage unit **130** is a part of the environment map generating unit **110** is shown in FIG. **4**, the present invention is not limited to such an example, and the data storage unit **130** may be provided outside the environment map generating unit **110**. FIG. **9** is an illustrative diagram for illustrating an example of a configuration of the feature data.

Referring to FIG. **9**, feature data FD**1** is shown as an example for the object Obj**1**. The feature data FD**1** includes an object name FD**11**, image data FD**12** taken from six directions, patch data FD**13**, three-dimensional shape data FD**14** and ontology data FD**15**.

The object name FD**11** is the name by which a corresponding object may be specified such as a "coffee cup A."

The image data FD**12** includes six image data obtained by taking images of the corresponding object from six directions: front, back, left, right, above and below, for example. The patch data FD**13** is a set of small images around each FP for each of one or more FPs set on each object. The image data FD**12** and the patch data FD**13** may be used for an object recognition process in the image recognizing unit **140**, which will be described later. Also, the patch data FD**13** may be used for the above-described self-position detection process in the self-position detecting unit **120**.

The three-dimensional shape data FD**14** includes polygon information for recognizing a shape of the corresponding object and three-dimensional positional information of FPs. The three-dimensional shape data FD**14** may be used for an environment map building process in the environment map building unit **150**, which will be described later.

The ontology data FD**15** is the data that may be used to support the environment map building process in the environ-

ment map building unit **150**, for example. In the example of FIG. **9**, the ontology data FD**15** indicates that the object Obj**1**, which is the coffee cup, is more likely to come in contact with an object corresponding to a desk or a dishwasher and is less likely to come in contact with an object corresponding to a bookshelf.

(3) Image Recognizing Unit

The image recognizing unit **140** specifies objects to which physical objects present in the input image correspond, using the above-described feature data stored in the data storage unit **130**.

FIG. **10** is a flowchart showing an example of flow of the object recognition process in the image recognizing unit **140**. Referring to FIG. **10**, first, the image recognizing unit **140** acquires the input image from the imaging unit **102** (step S**212**). Next, the image recognizing unit **140** matches partial images included in the input image against patches of one or more FPs of each object included in the feature data to extract FPs included in the input image (step S**214**). The FPs used in the object recognition process in the image recognizing unit **140** and the FPs used in the self-position detection process in the self-position detecting unit **120** are not necessarily the same. However, when common FPs are used in the both processes, the image recognizing unit **140** may reuse the result of FP tracking by the self-position detecting unit **120**.

Next, the image recognizing unit **140** specifies the object present in the input image based on the result of extracting the FP (step S**216**). For example, when the FPs belonging to one object are extracted with high density in a certain area, the image recognizing unit **140** may recognize that the object is present in the area. The image recognizing unit **140** outputs the object name (or an identifier) of the specified object and the position of the FP belonging to the object on the imaging plane to the environment map building unit **150** (step S**218**).

(4) Environment Map Building Unit

The environment map building unit **150** generates the environment map using the position and the posture of the camera input from the self-position detecting unit **120**, the positions of the FPs on the imaging plane input from the image recognizing unit **140** and the feature data stored in the data storage unit **130**. In this disclosure, the environment map is a set of data indicating positions (and postures) of one or more objects present in the real space. The environment map may include object names corresponding to objects, the three-dimensional positions of FPs belonging to objects and the polygon information configuring shapes of objects, for example. The environment map may be built by obtaining the three-dimensional position of each FP according to the above-described pinhole model from the position of the FP on the imaging plane input from the image recognizing unit **140**, for example.

By changing the relation equation of the pinhole model expressed in Equation (11), the three-dimensional position pi of the FP FP_i in the global coordinate system may be obtained by the following equation.

[Equation 12]

$$p_i = x + \lambda \cdot R_\omega^T \cdot A^{-1} \cdot \tilde{p}_i = x + d \cdot R_\omega^T \frac{A^{-1} \cdot \tilde{p}_i}{\|A^{-1} \cdot \tilde{p}_i\|} \quad (14)$$

Herein, d denotes a distance between the camera and each FP in the global coordinate system. The environment map building unit **150** may calculate such a distance d based on the positions of at least four FPs on the imaging plane and the distance between the FPs for each object. The distance between the FPs is stored in advance in the data storage unit **130** as the three-dimensional shape data FD**14** included in the feature data described with reference to FIG. **9**. It should be noted that a calculation process of the distance d in Equation (14) is disclosed in detail in Japanese Patent Application Laid-Open Publication No. 2008-304268

After the distance d is calculated, remaining variables of a right side of Equation (14) are the position and the posture of the camera input from the self-position detecting unit **120** and the position of the FP on the imaging plane input from the image recognizing unit **140**, all of which are known. The environment map building unit **150** then calculates the three-dimensional position in the global coordinate system for each FP input from the image recognizing unit **140** according to Equation (14). The environment map building unit **150** then builds a latest environment map according to the three-dimensional position of each calculated FP and allows the environment map storage unit **152** to store the built environment map. It should be noted that, at that time, the environment map building unit **150** may improve accuracy of the data of the environment map using the ontology data FD**15** included in the feature data described with reference to FIG. **9**.

The environment map storage unit **152** stores the environment map built by the environment map building unit **150** using the storage medium such as the hard disk or the semiconductor memory.

[2-3. Output Image Generating Unit]

The output image generating unit **180** generates, for a set of procedures of the operation to be performed in the real space, an output image for presenting the direction for each procedure to the user and displays the generated output image on the display device **104**. In this case, the output image generating unit **180** associates a given position in the environment map generated by the environment map generating unit **110** with the direction for each procedure, and superimposes the direction for each procedure at a position in the input image corresponding to the given position. As shown in FIG. **4**, in the present embodiment, the output image generating unit **180** includes a procedure storage unit **184**, a procedure control unit **186**, an information arrangement unit **190**, and a superimposing unit **192**.

(1) Procedure Storage Unit

The procedure storage unit **184** stores procedure data defined by causing the direction for each procedure to correspond to the position information designating a position at which the direction is to be displayed, for a set of procedures of operation to be performed in the real space, using a storage medium such as hard disk or a semiconductor memory.

FIG. **11** is an illustrative diagram for illustrating procedure data **182**, for example, stored in the procedure storage unit **184** according to the present embodiment. Referring to FIG. **11**, the procedure data **182** has five data items such as "name of directions," "procedure ID," "procedure direction," "related physical object" and "progress condition."

The "name of directions" is a name assigned to each operation to be performed in the real space. Procedure data about a set of procedures for one operation can be acquired by designating one name of directions. In the example of FIG. **11**, procedure data of two operations: "table manners" and "frying eggs" is included in the procedure data **182**.

The "procedure ID" is an identifier for identifying each procedure included in the set of procedures. In the example of FIG. **11**, the procedure data for the "table manners" includes three procedures of procedure IDs: "P101," "P102" and

"P103," Also, the procedure data for "frying eggs" includes four procedures of procedure IDs: "P201," "P202," "P203" and "P204."

The "procedure direction" is a character string indicating the direction for each procedure to be present to the user. In the example of FIG. **11**, the procedure direction of the procedure of procedure ID="P101" of the "table manners" (hereinafter, referred to as procedure P101) is a character string: "sit from a left side of a chair." The procedure direction of procedure P102 is a character string: "order food and drink." The procedure direction of procedure P103 is a character string: "set a napkin on your lap." Also, the procedure direction of procedure P201 of "frying eggs" is a character string: "divide and stir eggs." The procedure direction of the procedure P202 is a character string: "move the frying pan to the stove." The procedure direction of the procedure P203 is a character string: "put the eggs onto the frying pan." The procedure direction of procedure P204 is a character string: "sprinkle salt and pepper."

The "related physical object" is position information designating a position at which each procedure direction is to be displayed, using an object name for specifying a physical object associated with each procedure direction. For example, in the present embodiment, each procedure direction is displayed in the vicinity of the physical object specified by the "related physical object." In the example of FIG. **11**, the related physical object of procedure P101 of the "table manners" is a "chair." That is, the procedure direction of procedure P101 can be displayed in the vicinity of the chair included in the environment map. The related physical object of procedure P102 is a "menu." That is, the procedure direction of the procedure P102 can be displayed in the vicinity of the menu included in the environment map. The related physical object of the procedure P103 is a "napkin." That is, the procedure direction of the procedure P103 can be displayed in the vicinity of the napkin included in the environment map. Further, for example, the "related physical object" for a procedure not associated with any physical object is blank and the procedure direction of this procedure may be displayed in a specific position such as a center of the screen.

The "progress condition" indicates a condition for progressing a displaying process from each procedure to a next procedure when the image processing device **100** displays a set of procedures. That is, the progress condition may be said to be information designating timing when each procedure direction is to be displayed. In the example of FIG. **11**, the progress condition is defined according any one or combination of the following three patterns.

First pattern: a state of the physical object in the environment map

Second pattern: passage of a given time

Third pattern: an external event

The first pattern is a pattern in which the progress condition is satisfied (i.e., the displaying process proceeds to a next procedure) when the position or posture of the physical object represented by the environment map is in a given state. For example, the progress condition of the procedure P102 of the procedure data **182** is that "a menu is put down." Such a progress condition may be satisfied, for example, when the menu is not present on the table in the environment map. Also, for example, the progress condition of the procedure P103 of the procedure data **182** is that "the napkin is on the chair." Such a progress condition may be satisfied, for example, when in the environment map when the napkin moves from on the table to over the chair (e.g., on the lap of the user seated on the chair).

The second pattern is a pattern in which the progress condition is satisfied when a given time has elapsed from displaying of a preceding procedure direction or generation of another event. For example, the progress condition of the procedure P201 of the procedure data **182** is a "passage of one minute." Such a progress condition may be satisfied when one minute has elapsed after the procedure direction of the procedure P201 is displayed. Also, for example, the progress condition of the procedure P203 of the procedure data **182** is a "passage of 30 seconds from stove ignition." Such a progress condition may be satisfied, for example, when 30 seconds have elapsed from a stove ignition event notified of from an external device (stove).

The third pattern is a pattern in which the progress condition is satisfied when there has been a given event notification from another device. For example, the progress condition of the procedure P202 of the procedure data **182** is that "the frying pan is on the stove." Such a progress condition may be satisfied, for example, when the event is notified of from the stove having detected the frying pan being on the stove, for example, using a pressure sensor. Further, the satisfaction of the condition: "there is a frying pan on a stove" may be determined from a state of the physical object in the environment map (in this case, which is the first pattern). An event notification from another device is not limited to such an example, but may be, for example, a notification of the image recognition result (e.g., the result of recognizing a state of a user's hand) from the imaging device, a notification about a user manipulation from an electronic device, a notification about signal reception from a communication device, or the like.

The procedure storage unit **184** stores such procedure data **182** as an example, and outputs at least part of the procedure data **182** according to a request from the procedure control unit **186**, which will be described later. Further, in the example of FIG. **4**, the procedure storage unit **184** is provided inside the image processing device **100**. However, the prevent invention is not limited to such an example, but the procedure data may be stored in a storage medium external to the image processing device **100**. In this case, the image processing device **100** may selectively acquire necessary procedure data from the external storage medium, for example, according to an instruction of the user. Also, a plurality of procedures whose states transition from each other as in a state machine may be defined as procedure data instead of a sequential procedure such as the procedure data **182** illustrated in FIG. **11**.

(2) Procedure Control Unit

The procedure control unit **186** acquires procedure data for a desired name of directions from the procedure storage unit **184**, for example, according to an instruction from the user, and controls displaying of the procedure direction for each procedure included in the set of procedures according to the acquired procedure data.

FIG. **12** is a flowchart showing an example of flow of a procedure control process in the procedure control unit **186** according to the present embodiment. Referring to FIG. **12**, first, the procedure control unit **186** acquires procedure data for a desired name of directions from the procedure storage unit **184** (step S**302**). For example, when the user designates "table manners" as the name of directions, the procedure control unit **186** acquires procedure data for the "table manners" including the set of procedures P101, P102, P103, . . . illustrated in FIG. **11**.

Next, the procedure control unit **186** reads a first procedure from the acquired procedure data (step S**304**). For example, when the procedure data including the set of procedures

P101, P102, P103 . . . illustrated in FIG. **11** is acquired, the procedure control unit **186** initially reads a record of the procedure P101.

Next, the procedure control unit **186** displays a procedure direction in the vicinity of a related physical object corresponding to the read procedure (step S**306**). More specifically, the procedure control unit **186** specifies, for example, in the environment map, a position of the related physical object corresponding to the read procedure, and determines the vicinity of the position of the related physical object as a three-dimensional position at which the procedure direction is to be displayed. The procedure control unit **186** outputs the procedure direction and the three-dimensional position at which the procedure direction is to be displayed, to the information arrangement unit **190**. A subsequent procedure displaying process will be described in greater detail later.

Next, the procedure control unit **186** monitors a state of the physical object, passage of a given time, an external event, or the like in the environment map according to the progress condition corresponding to the read procedure (step S**308**). When the progress condition is satisfied as a result of monitoring, the process proceeds to step S**310**.

Next, the procedure control unit **186** determines whether a next procedure that has not been displayed remains (step S**310**). Here, when the next procedure that has not been displayed remains, the process returns to step S**304** and the procedure displaying process is repeated for a next procedure. On the other hand, when the next procedure that has not been displayed does not remain, the procedure control process in the procedure control unit **186** ends.

(4) Information Arrangement Unit

The information arrangement unit **190** calculates a position in the input image at which each procedure direction input from the procedure control unit **186** is to be displayed, according to Equation of the pinhole model using the position and posture of the imaging device acquired from the environment map generating unit **110**. In this case, the three-dimensional position p_i of the FP FP_i at the right side of Equation (11) is substituted with the three-dimensional position input from the procedure control unit **186**. After the information arrangement unit **190** calculates the position in the input image at which each procedure direction is to be displayed, the information arrangement unit **190** outputs each procedure direction and the position in the input image at which the procedure direction is to be displayed, to the superimposing unit **192**.

(5) Superimposing Unit

The superimposing unit **192** generates an output image by superimposing each procedure direction input from the information arrangement unit **190** at the position in the input image calculated by the information arrangement unit **190**.

FIG. **13** is a flowchart showing an example of flow of a procedure displaying process in the procedure control unit **186**, the information arrangement unit **190** and the superimposing unit **192**. Further, the procedure displaying process shown in FIG. **13** is executed in step S**306** in the procedure control process shown in FIG. **12** for each individual procedure included in a set of procedures of operation to be performed in the real space.

Referring to FIG. **13**, first, the procedure control unit **186** determines the three-dimensional position at which the procedure direction is to be displayed, based on a position of a related physical object in the environment map (step S**322**). For example, when the related physical object for any procedure is on a chair, a position of either a surface or the vicinity of the chair in the environment map is determined as the three-dimensional position at which the procedure direction for the procedure is to be displayed.

Next, the information arrangement unit **190** calculates the position in the input image corresponding to the three-dimensional position determined in step S**322** according to the pinhole model using the position and posture of the imaging device acquired from the environment map generating unit **110** (step S**324**). Further, when the position on the imaging plane corresponding to the three-dimensional position determined in step S**322** is out of a range of the input image, a subsequent process may be skipped.

Next, the superimposing unit **192** generates an output image by superimposing, for example, a text box describing the procedure direction at the position in the input image calculated by the information arrangement unit **190** (step S**326**). The output image generated by the superimposing unit **192** is displayed, for example, on the screen of the display device **104** of the image processing device **100**.

[2-4. Example of Output Image]

FIGS. **14** and **15** show examples of an output image that can be displayed on the screen of the display device **104** in the present embodiment, respectively.

Referring to FIG. **14**, an output image Im**11** on which the procedure direction for the procedure P202 illustrated in FIG. **11** is superimposed is shown. In the output image Im**11**, a text box T**11** describing a procedure direction "procedure 2: move the frying pan to the stove" is displayed in the vicinity of the frying pan. The user can intuitively recognize that it is good for the frying pan to be on the stove in a next cooking procedure by viewing such a procedure direction. This text box T**11** continues to be displayed in the vicinity of the frying pan until a state "the frying pan is on the stove," which is the progress condition of the procedure P202, is realized in the environment map. Thus, the user can easily recognize a physical object serving as an object of the procedure.

Referring to FIG. **15**, an output image Im**21** on which a procedure direction for the procedure P103 illustrated in FIG. **11** is superimposed is shown. In the output image Im**21**, a text box T**21** describing a procedure direction "procedure3: set a napkin in your lap" is displayed in the vicinity of the napkin. The user can intuitively recognize that it is good for the napkin to be set on the lap in a next procedure of the table manners by viewing such a procedure direction. This text box **121** continues to be displayed in the vicinity of the napkin until a state "the napkin is on the chair," which is the progress condition of the procedure P103, is realized in the environment map. Thus, the user can easily recognize a physical object serving as an object of the procedure.

The procedure display method described herein is only an example, and various applications are possible, in addition to the above-described embodiment. For example, the present invention may be applied for directions in spaces such as commercial facilities or train stations or for manipulation directions in a rent-a-car or an automated teller machine (ATM).

3. EXAMPLE OF HARDWARE CONFIGURATION

It does not matter whether a set of processes according to the above-described embodiment are realized by hardware or software. When a set of processes or a part of the same is executed by the software, a program composing the software is executed using a computer incorporated in dedicated hardware or a general-purpose computer shown in FIG. **16**, for example.

In FIG. **16**, the CPU **902** controls entire operation of the general-purpose computer. A program or data describing some or all of the processes in the set is stored in a read only memory (ROM) **904**. The program and data used by the CPU **902** in process execution are temporarily stored in a random access memory (RAM) **906**.

The CPU **902**, the ROM **904**, and the RAM **906** are connected to each other via a bus **910**. Further, an input/output interface **912** is connected to the bus **910**.

The input/output interface **912** is an interface for connecting the CPU **902**, the ROM **904**, and the RAM **906** with the input device **920**, the display device **104**, the storage device **924**, the imaging device **102**, and the drive **930**.

The input device **920** receives instructions or information input from the user, for example, via an input interface such as a button, a switch, a lever, a mouse, or a keyboard. The storage device **924** includes, for example, a hard disk drive or a semiconductor memory, and stores programs or data. The drive **930** is provided in the general-purpose computer as necessary and, for example, a removable media **932** is mounted in the drive **930**.

When the set of processes is executed by software, for example, a program stored in the ROM **904**, the storage device **924**, or the removable media **932** shown in FIG. **16**, when executed, is read into the RAM **906** and then executed by the CPU **902**.

4. CONCLUSION

The embodiment of the present invention has been described with reference to FIGS. **1**A to **16**. According to the present embodiment, the direction for each procedure included in the set of procedures of the operation to be performed in the real space is displayed at the position determined based on the environment map, which three-dimensionally represents a position of a physical object present in the real space. Accordingly, the procedure can be intuitively understood by the user. In particular, according to the present embodiment, the environment map is dynamically updated to follow a change in the environment even in the operation in the real space in which an environment surrounding the user may be dynamically changed. As a result, the position at which the direction for each procedure is displayed moves according to the change of the environment, thereby preventing difficulty in understanding of the directions from being caused due to the change of the environment.

Also, in the present embodiment, the position at which the direction for each procedure is to be displayed can be determined according to the position of the physical object associated with the direction for each procedure. Accordingly, it is possible for the user to easily recognize the physical object as a target object of the operation in each procedure. Also, since the timing when the direction for each procedure is to be displayed is controlled according to the state (position or posture) of the physical object in the environment map, passage of a given time, an external event or the like, the direction can be displayed at proper timing according to the progress of the operation by the user. Further, the position at which the direction for each procedure is to be displayed is calculated based on the position and posture of the camera dynamically detected using SLAM technology. Accordingly, even when a camera whose position or posture is likely to be changed from moment to moment is used, the direction can be displayed in a proper position in the image.

The preferred embodiments of the present invention have been described above with reference to the accompanying drawings, whilst the present invention is not limited to the above examples, of course. A person skilled in the art may find various alternations and modifications within the scope of the appended claims, and it should be understood that they will naturally come under the technical scope of the present invention.

What is claimed is:

1. An image processing device comprising:

a control unit configured to acquire procedure data for a set of procedures of operation to be performed in a real space, the procedure data defining a correspondence between a direction for each procedure and position information designating a position at which the direction is to be displayed; and

a superimposing unit configured to generate an output image by superimposing the direction for each procedure included in the set of procedures at a position in the input image determined based on an environment information representing a position of one or more physical objects present in the real space and the position information, using the procedure data acquired by the control unit,

wherein the procedure data defines a further correspondence between the direction for each procedure and a condition for progressing displaying of each direction, and

wherein the control unit and the superimposing unit are each implemented via at least one processor.

2. The image processing device according to claim **1**,

wherein the position information designates a position at which the direction is to be displayed, by specifying a physical object related to the direction for each procedure.

3. The image processing device according to claim **1**,

wherein the condition for progressing displaying of each direction includes a condition according to a position or a posture of a physical object.

4. The image processing device according to claim **1**,

wherein the control unit controls displaying of the direction for each procedure included in the set of procedures according to the procedure data.

5. An image processing method in an image processing device including a storage medium having feature data stored therein, the feature data indicating a feature of appearance of one or more physical objects, the method comprising the steps of:

acquiring procedure data for a set of procedures of operation to be performed in a real space, the procedure data defining a correspondence between a direction for each procedure and position information designating a position at which the direction is to be displayed; and

generating an output image by superimposing the direction for each procedure included in the set of procedures at a position in the input image determined based on an environment information representing a position of one or more physical objects present in the real space and the position information, using the acquired procedure data,

wherein the procedure data defines a further correspondence between the direction for each procedure and a condition for progressing displaying of each direction.

6. A non-transitory computer-readable medium having embodied thereon a program, which when executed by a computer that controls an image processing device including a storage medium having feature data stored therein, the feature data indicating a feature of appearance of one or more physical objects, causes the computer to perform a method comprising:

acquiring procedure data for a set of procedures of operation to be performed in a real space, the procedure data defining a correspondence between a direction for each procedure and position information designating a position at which the direction is to be displayed; and

generating an output image by superimposing the direction for each procedure included in the set of procedures at a position in the input image determined based on an environment information representing a position of one or more physical objects present in the real space and the position information, using the acquired procedure data,

wherein the procedure data defines a further correspondence between the direction for each procedure and a condition for progressing displaying of each direction.

7. An image processing device comprising:

a control unit configured to acquire procedure data for a set of procedures of operation to be performed in a real space, the procedure data defining a correspondence between a direction for each procedure and position information designating a position at which the direction is to be displayed; and

a superimposing unit configured to generate an output image by superimposing the direction for each procedure included in the set of procedures at a position in the input image determined based on an environment information representing a position of one or more physical objects present in the real space and the position information, using the procedure data acquired by the control unit,

wherein the procedure data further defines a correspondence between each of a plurality of physical objects present in the real space and respective progress conditions, and

wherein the control unit and the superimposing unit are each implemented via at least one processor.

8. The image processing device according to claim **7**,

wherein the progress conditions indicate a condition in correspondence with respective ones of the physical objects, upon which the direction for each procedure is to be displayed.

9. The image processing device according to claim **8**,

wherein the direction for each procedure is respectively displayed when a progress condition associated with a corresponding one of the plurality of physical objects is determined to correspond to a present condition in the real space.

* * * * *